Turbulence-induced self-focusing and filamentation

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Filamentation denotes the process in which high-power, ultra-short laser pulses overcome a critical threshold above which nonlinear effects of the medium come into play. In doing so, the laser pulse can guide itself while propagating - thus creating a kind of thread or filament - instead of simply diffracting as one would normally expect [1],[2]. This self-guidance relies on a balancing act between the nonlinear Kerr effect that focuses the beam, and a defocusing caused by ionization of the medium and polarisability inversion [3]. Filaments can span over tens to hundreds of meters, and be initiated at kilometer-range distances. Therefore, filaments are promising candidates for innovative applications in several atmospheric fields like remote sensing [4], or laser-induced condensation [5].

In any application, an important factor to take into account is the interaction of the laser pulse with a turbulent atmosphere, both before and during the filamentation process. A remarkable feature of filaments is that once formed, they are rather robust to turbulence. However, in the stage before the filament has formed, the interaction with turbulence can have the seemingly opposite effects of either helping or hindering filament nucleation and increasing or decreasing the initiation distance. The effect depends on factors such as beam power, size and coherence on one hand, and the turbulence strength and its length scales on the other [6].

Here, we show that a strongly turbulent environment can be used to trigger filamentation for a laser beam that would not have enough power to filament in a calm atmosphere. This suggests that turbulence seeds modulation instability, i.e. the rapid growth of a perturbation in the beam, causing the onset of filaments. We believe this sub-threshold onset is an area of turbulence-filament interaction that has not yet been explored. Our setup consists of a collimated femto-second laser, propagating through a small turbulent air region followed by a water-cell. Because the nonlinear refractive index of water is about three orders of magnitude higher than of air [1], this table-top experiment allows us to see effects that would otherwise require long range propagation in air.

Références

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